Juvenile Salmon Utilization of Sinclair Inlet, an Urban Embayment

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Abstract
Sinclair Inlet is a large, enclosed embayment located in Central Puget Sound where the quality of habitat, water and sediment has all been significantly modified. Since 2001, we have investigated the ecology of juvenile salmonids, especially juvenile chinook, associated with littoral and offshore habitats of the Inlet using beach seines, surface trawls, and purse seines. We found juvenile chinook in littoral areas of Sinclair Inlet from April through the end of September when sampling ended. Juvenile chum occurred in littoral areas of the bay from March through September while coho were rarely caught. Juvenile salmonids were abundant along both shorelines and in all habitat types. Most juvenile chinook using the bay had been released from the Gorst Creek rearing ponds. We released a large number of marked hatchery juvenile chinook into Gorst Creek to evaluate residence time and found that the fish spent up to three months in the bay. There was also a steady increase in size of chinook caught in the Inlet that also indicates some chinook were rearing for extended periods in the Inlet. We also found large juvenile chum (> 150 mm) in the bay in late September, indicating extended use of the bay by this species as well.

Introduction
Sinclair Inlet is a large, partially enclosed embayment located in Puget Sound, Washington that has been significantly modified by transportation, commercial and residential development. Most of the changes in the area are a result of the Puget Sound Naval Station (PSNS) Bremerton and the cities and ports of Bremerton and Port Orchard. In 2001 and 2002, we investigated the ecology of juvenile salmonids using Sinclair Inlet. We studied juvenile salmon use of this area because little is known about how salmon juveniles use developed shorelines, especially in areas distant from natal streams. Specific objectives of this work were to document the spatial and temporal distribution and relative abundance of juvenile salmon in the Inlet; determine if spatial and temporal patterns existed based upon size, species and origin (hatchery vs wild) of the fish; estimate residence time of juvenile chinook using the Inlet; and determine if selected habitat factors were related to use of littoral zone areas. Although we collected information on all fish that were captured, this report focuses on results for juvenile chinook salmon because this species has been listed in Puget Sound as threatened under the U.S. Endangered Species Act.

Methods
Our study area included the western portion of Port Orchard bound by the Washington Narrows Bridge, the western entrance of Rich Passage and the southern tip of Bainbridge Island. Within this region, we defined three areas for sampling purposes. Area 1 was the western most portion of the study area. Most of the development in Area 1 was residential although much of the shoreline has been armored. Area 2 was the central portion of our study area and was the most heavily developed as it included the PSNS, Bremerton, and Port Orchard. Area 3 was the eastern most portion of the study area. The western end of Area 3 included portions of Port Orchard and Bremerton while residential development predominated in the rest of the Area

Our basic methods of sampling employed beach seines in littoral areas and surface tow nets in nearshore surface waters. Beach seining was used to sample littoral zone habitats in both 2001 and 2002 while tow nets were only used in 2002. The beach seine used and method employed to set and retrieve the net was the same as that described in Miller et al. (1977) and Fresh et al. (1979). In 2001 and 2002, littoral zone fish were sampled at least once at 24 sites in the Inlet although only a limited number of these sites were sampled regularly. The most consistently sampled sites were distributed throughout the study area and represented a variety of habitat types. In 2001, littoral zone sampling began in April and continued approximately monthly through early October while in 2002, collections were made approximately every three weeks from mid-February through early September.

Surface tow netting collected fish from the upper 3m of the water column and closely followed the approach described by Fresh (1979) and Fresh et al. (1979). Tow net samples were obtained monthly during May, June, July and August 2002. Sampling occurred during day and night hours, along both shorelines, and in the center of each area. All tows were 10 minutes in duration, with the exception of several tows during May that were reduced to 5 minutes due to high catches of ctenophores (jellies).

Residence time studies were conducted only in 2002 using hatchery produced juvenile chinook released from Gorst Creek. We used fluorescent pigment and coded wired tags (CWT) to mark the fish. The basic approach used for fluorescent pigment was similar to that employed by Bax (1983), Phinney and Mathews (1969) and Fresh and Schroder (1987) and involved using compressed air to force pigment granules to adhere to the fish. We marked over 120,000 juvenile chinook with fluorescent pigment, CWTs, or some combination of the two. These fish were released in six different groups beginning in mid-May. To calculate residence time of marked fish, we sampled 12 sites every 3-4 days for approximately one month to recover marks. We also recorded marks recovered during the regular beach seining and surface townetting operations.

Standard catch processing procedures were used for all samples. We enumerated the catch by species and measured the length of all salmonids or a subsample. In addition, juvenile chinook were examined for the presence of coded wire tags, adipose clips, and pigment. All chinook with intact adipose fins were assumed to be "wild" fish and are referred to as wild in this report. A juvenile chinook with any type of mark was classified as a hatchery fish. Because of incomplete marking of hatchery chinook and coho populations, the proportion of "wild" fish will be overestimated.

Results and Discussion

In littoral areas of Sinclair Inlet, juvenile chum salmon was the dominant species of salmonid caught during both years of the study. For example, in 2002, about 78% of all juvenile salmonids caught were chum salmon. These fish could potentially have come from a variety of sources that are both local and distant and could include both hatchery produced (e.g., egg boxes) and naturally-produced fish. In nearshore surface waters of the Inlet, juvenile chinook was the dominant salmonid species. Few coho salmon were caught in either littoral or offshore habitats. About 10% of the juvenile chinook collected each year and in each major habitat type (littoral versus offshore) were unclipped subyearlings that were classified as wild fish. In littoral areas, juvenile chinook were caught from April-September in 2001 and from May-September in 2002. In 2002, juvenile chinook were not caught either by beach seining or tow netting until after releases of hatchery fish into Gorst Creek began in mid-May. Peak catches of juvenile chinook in littoral and surface waters occurred in June.

We correlated catch of wild and hatchery juvenile chinook with Area (1, 2, or 3), shoreline (North vs South shoreline), offshore vs. littoral habitat, and site specific habitat characteristics (e.g., substrate, slope, and vegetation) of littoral areas. We found no relationship between juvenile chinook catch and offshore vs inshore habitat type or between juvenile chinook catch and site specific habitat characteristics of littoral areas. Spatial distribution of juvenile chinook was correlated with both area and shoreline (north vs south shoreline). Catches of chinook juveniles generally declined from Area 1 to Area 3, probably reflecting the passage and dispersal of juvenile chinook from Gorst Creek through Sinclair Inlet. In the eastern part of Sinclair Inlet, juvenile chinook catches are greatest probably because most fish are from Gorst Creek and they are more concentrated near their release location. As they migrate east away from their release site, the fish disperse and their density consequently declines.

Catches along the north shoreline were greater than along the south shoreline for both hatchery and wild origin juvenile chinook during both years of the study. For example, overall CPUE of hatchery fish in 2002 along the north shore was nearly nine times greater than along the south shore. We speculate that prevailing currents may push juvenile chinook entering Sinclair Inlet from Gorst Creek towards the north shore.

Size of juvenile chinook increased in the Inlet from June until September. We caught some small chinook fry (< 50 mm) in the Inlet in April, 2001 that could be the progeny of naturally spawning fish as hatchery fish were not released until May. In general, sizes of clipped and unclipped chinook were comparable when compared at the same time and from the same habitat type. There was some evidence that size of juvenile chinook increased from Area 1 (west end of the Inlet) to Area 3 probably reflecting the growth of fish during their passage through the Inlet.

Fluorescent pigment marked and CWT chinook released into Gorst Creek were used to estimate residence time. Average residence time in Area 1 and Area 2 (average of separate estimates made for the 6 groups) was 6.2 days and 8.3 days, respectively. The estimated maximum residence time for any group released into Sinclair Inlet was 59 days.

As noted above, most (90%) juvenile chinook using Sinclair Inlet were of hatchery origin. Hatchery produced juvenile chinook can potentially originate from local streams or from distant locations such as the large rivers draining into the main basin of Puget Sound. The closest source of hatchery juvenile chinook using Sinclair Inlet was Gorst Creek which typically releases up to 2 million juvenile chinook each year. Small numbers of hatchery produced fish occasionally spawn naturally in Gorst Creek and perhaps in some other adjacent streams.

The origin of the hatchery fish using Sinclair Inlet was evaluated using recoveries of coded wire tagged (CWT) fish. We found that CWT chinook recovered from Sinclair Inlet originated from 15 different locations that were as far away as the Chilliwak River in the Fraser River Basin. A total of 77% of these recoveries were hatchery fish released into Gorst Creek. Fish from some of these release sites appeared to disperse quickly. For example, juvenile chinook released from the Green River were recovered within 11 days of release while fish released 25 km away from Sinclair Inlet into Grovers Creek were recovered within 48 hours in Sinclair Inlet. Before 7/15/02, 90% of the hatchery fish found in Sinclair Inlet were from Gorst Creek while after 7/15/02, 33% of the CWT fish recovered from this area were from Gorst Creek. These data in combination with residence time estimates suggest that juvenile chinook from Gorst Creek rapidly leave Sinclair Inlet and are replaced by non-natal fish later in the year. We do not know if wild fish exhibit the same type of migratory behavior.

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